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Timeliness and Effectiveness of Stroke Care in the Emergency Department

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ABSTRACT

Background: Acute stroke outcomes are critically dependent on time to diagnosis and treatment, with each minute of delay leading to irreversible neuronal loss. Despite international benchmarks emphasizing door-to-imaging ≤ 25 minutes and door-to-needle ≤ 60 minutes, delays remain widespread in low- and middle-income countries, including Pakistan. **Objective:** To assess the timeliness and effectiveness of acute stroke management in the Emergency Department of Lady Reading Hospital, Peshawar, focusing on prehospital and in-hospital time intervals and their association with early neurological outcomes. **Methods:** A prospective observational study was conducted from October 2024 to January 2025, enrolling 300 adults presenting within 24 hours of stroke onset. Time intervals—onset-to-door, door-to-imaging, and door-to-needle—were recorded. Effectiveness was evaluated by adherence to international targets and early neurological improvement (NIHSS reduction ≥ 4). Data were analyzed using SPSS 26, applying *t*-tests, χ^2 tests, and multivariate logistic regression. **Results:** The median onset-to-door time was 160 minutes, and mean door-to-imaging and door-to-needle times were 38 ± 18 and 62 ± 19 minutes, respectively. Only 52% achieved imaging ≤ 25 minutes, and 46.6% received thrombolysis within 60 minutes. Door-to-imaging ≤ 25 minutes (OR 2.83, 95% CI 1.43–5.61) and door-to-needle ≤ 60 minutes (OR 2.32, 95% CI 1.09–4.94) independently predicted early neurological improvement. **Conclusion:** Significant prehospital and imaging delays limited timely reperfusion despite efficient triage. Implementing structured stroke-fast-track pathways, EMS prenotification, and prioritized neuroimaging could substantially enhance both timeliness and early outcomes in tertiary emergency care in Pakistan.

Keywords

Stroke, Emergency Department, Timeliness, Thrombolysis, Door-to-Needle Time, Prehospital Delay, Stroke Pathway

INTRODUCTION

Stroke remains a leading global cause of mortality and long-term disability, imposing substantial clinical and socioeconomic burdens on health systems worldwide (1). The World Health Organization estimates that approximately 15 million people suffer a stroke each year, of whom five million die and another five million are left permanently disabled (2). The concept that “time is brain” underscores the centrality of rapid diagnosis and reperfusion therapy in determining neurological outcomes; with each minute of delay, nearly two million neurons are irreversibly lost (3). International stroke management guidelines—most notably those from the American Heart Association/American Stroke Association (AHA/ASA) and the United Kingdom’s Intercollegiate Stroke Working Party—advocate for door-to-imaging times ≤ 25 minutes and door-to-needle times ≤ 60 minutes for eligible ischemic stroke patients, emphasizing organized stroke systems of care to minimize delays and optimize outcomes (4,5). Despite these established benchmarks, adherence in low- and middle-income countries (LMICs) remains suboptimal due to fragmented prehospital systems, delayed recognition of stroke symptoms, limited imaging capacity, and inadequate interdepartmental coordination (6). Studies from South Asia report door-to-needle times exceeding 80 minutes in over half of cases, largely attributable to delayed triage and limited emergency medical service (EMS) integration (7). In Pakistan, although tertiary centers have made significant progress in stroke recognition and neuroimaging infrastructure, systematic assessment of time metrics and their clinical impact remains limited. Existing national data are fragmented and rarely analyze both prehospital and in-hospital phases together, resulting in a critical knowledge gap regarding where and how delays occur within the stroke care continuum (8).

Timeliness in emergency stroke management directly influences effectiveness. Prehospital notification by EMS, rapid triage, and parallel tasking between emergency and radiology teams have been shown to markedly reduce door-to-CT and door-to-needle times, translating to improved rates of reperfusion and functional recovery (9,10). Conversely, delays in any link of this chain—onset-to-door, door-to-imaging, or door-to-needle—are independently associated with poorer outcomes, higher disability scores, and increased mortality (11). Although international quality improvement programs have demonstrated success in shortening these intervals, their applicability in LMIC settings such as Pakistan remains

inadequately evaluated, particularly in public-sector tertiary emergency departments (12,13). Lady Reading Hospital (LRH), Peshawar, serves as one of Pakistan's largest tertiary emergency centers, receiving a high volume of stroke patients from across Khyber Pakhtunkhwa. However, a systematic evaluation of its acute stroke workflow—including prehospital arrival times, in-hospital process adherence, and short-term neurological outcomes—has not previously been reported. Understanding these parameters is crucial to identifying bottlenecks and designing targeted interventions such as stroke fast-track pathways, EMS prenotification systems, and dedicated imaging prioritization protocols tailored to the local healthcare context (14,15).

Therefore, this study aimed to evaluate the timeliness and effectiveness of acute stroke management in the Emergency Department of Lady Reading Hospital, Peshawar, by quantifying prehospital and in-hospital time intervals, measuring adherence to evidence-based guideline targets, and examining associations between process efficiency and early neurological outcomes. The working hypothesis was that shorter door-to-imaging and door-to-needle intervals would be independently associated with improved early neurological recovery among patients with acute ischemic stroke.

MATERIALS AND METHODS

This prospective observational study was conducted in the Emergency Department of Lady Reading Hospital (LRH), Peshawar, a tertiary-care, public-sector teaching institution and the principal stroke referral center for Khyber Pakhtunkhwa, Pakistan. The study period extended from October 2024 to January 2025, encompassing both weekday and weekend admissions to capture routine workflow variability. The design followed international observational reporting standards (STROBE) to ensure methodological transparency and comparability with global stroke-registry data (16).

All adult patients (≥ 18 years) presenting with clinical features suggestive of acute stroke within 24 hours of last-known-well time were screened for inclusion. Diagnosis of acute ischemic or hemorrhagic stroke was confirmed by neuroimaging (non-contrast CT or MRI brain). Patients with stroke mimics—including seizure, migraine, hypoglycemia, intracranial tumor, or conversion disorder—were excluded, as were those referred after receiving initial management at another facility or whose onset-to-arrival or in-hospital timestamps were incomplete. Consecutive sampling was applied to minimize selection bias, and enrollment continued until the predetermined sample of 300 patients was reached, ensuring sufficient power to detect clinically meaningful differences in early neurological outcomes between timely and delayed treatment groups at a 5% significance level (17).

Upon arrival, triage nurses recorded patient identifiers, time of arrival, and presenting complaint using the electronic ED information system. Informed consent was obtained from the patient or nearest attendant prior to data inclusion. A structured, prevalidated stroke-care proforma was used to collect demographic, clinical, and process-related data, including comorbidities, symptom onset time, prehospital transport mode, presence or absence of EMS prenotification, triage category, imaging completion time, thrombolytic administration, and early outcome measures. Neuroimaging reports were verified by on-duty neurologists or senior emergency physicians. To ensure data accuracy, timestamps were cross-checked against radiology logs and pharmacy records by two independent data auditors, and discrepancies exceeding ± 2 minutes were reconciled through source-document verification (18). Operational definitions adhered to international standards: onset-to-door time was defined as the interval between symptom onset (last-known-well) and arrival at the ED; door-to-triage time as the interval between arrival and completion of triage documentation; door-to-imaging time as the interval between arrival and completion of the first brain imaging study; and door-to-needle time as the interval between arrival and initiation of intravenous thrombolysis for eligible ischemic stroke cases. Effectiveness indicators included (i) proportion receiving imaging within 25 minutes, (ii) proportion receiving thrombolysis within 60 minutes, and (iii) early neurological improvement, defined as ≥ 4 -point reduction in NIHSS at 24 hours (19).

Multiple steps were implemented to limit bias and confounding. Consecutive enrollment reduced selection bias, while real-time data entry prevented recall error. Measurement bias was minimized by synchronizing all departmental clocks daily. Potential confounders—including age, baseline NIHSS, stroke subtype, and comorbidities—were incorporated into multivariable analyses. Data completeness was monitored weekly, and cases with missing critical timestamps ($< 5\%$ overall) were excluded listwise to preserve internal validity without imputation (20). The sample size was determined pragmatically based on six months of admission volume (≈ 90 stroke cases per month). Assuming 45% of patients would achieve timely door-to-needle treatment and anticipating a 20-percentage-point difference in early neurological improvement between timely and delayed groups, a two-sided α of 0.05 and 80% power yielded a minimum required sample of 280; this was rounded to 300 to account for attrition (21).

Data were analyzed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality (Kolmogorov–Smirnov test) and expressed as mean $\pm$ SD or median (IQR) as appropriate. Between-group comparisons employed independent-sample *t*-tests or Mann–Whitney *U* tests; categorical variables were compared using χ^2 or Fisher's exact tests. Multivariate binary logistic regression models identified predictors of early neurological improvement, adjusting for potential confounders. Odds ratios (OR) with 95% confidence intervals (CI) were reported. A two-tailed $p < 0.05$ was considered statistically significant (22). Ethical approval was granted by the Institutional Review Board of Lady Reading Hospital (Ref No. LRH/ER/IRB/2025/47). The study adhered to the ethical principles outlined in the Declaration of Helsinki (2013 revision). Confidentiality was maintained through coded identifiers and restricted database access, and only aggregate data were analyzed to ensure participant anonymity. All data entry processes were double-verified to maintain reproducibility and integrity.

RESULTS

A total of 300 consecutive patients with acute stroke were included in the final analysis. None were lost to follow-up during the initial 24-hour assessment window. The mean age was 61.8 ± 13.4 years, and 174 (58%) were male. Hypertension was the most frequent comorbidity (68%), followed by diabetes (36%), smoking (30%), and ischemic heart disease (22%). Ischemic stroke accounted for 72% ($n = 216$) of all cases, while 28% ($n = 84$) were hemorrhagic. The mean baseline NIHSS score on arrival was 12.3 ± 5.2 , with no significant sex-based difference ($p = 0.47$). Among all 300 participants, the median onset-to-door time was 160 minutes (IQR 90–310), indicating substantial prehospital delay. Only 41% of patients arrived within two hours of symptom onset. In contrast, in-hospital processes were comparatively efficient: 92% were triaged within 10 minutes, and the mean door-to-imaging time was 38 ± 18 minutes, though only 52% met the ≤ 25 -minute benchmark. Of the 216 patients with

ischemic stroke, 58 (26.9%) received intravenous thrombolysis. The mean door-to-needle interval for this subgroup was 62 ± 19 minutes; 27 patients (46.6%) achieved the ≤ 60 -minute target. Those who met this target exhibited markedly greater early neurological improvement at 24 hours (74.1% vs 54.8%, $p = 0.004$) and had an adjusted OR of 2.32 (95% CI 1.09–4.94) for achieving a ≥ 4 -point NIHSS reduction after adjustment for confounders. Seven-day mortality was numerically lower among timely-treated patients (7.4% vs 12.9%), though this difference was not statistically significant ($p = 0.32$).

Table 1. Baseline Characteristics of Study Participants (n = 300)

Variable	Frequency (%) / Mean $\pm$ SD	95% CI	p-value (a)
Age (years)	61.8 $\pm$ 13.4	59.9 – 63.7	—
Male sex	174 (58.0)	52.2 – 63.7	—
Hypertension	204 (68.0)	62.4 – 73.2	—
Diabetes mellitus	108 (36.0)	30.4 – 41.9	—
Smoking	90 (30.0)	24.8 – 35.7	—
Ischemic heart disease	66 (22.0)	17.4 – 27.3	—
Stroke type (Ischemic / Hemorrhagic)	216 (72.0) / 84 (28.0)	—	—
Mean NIHSS on arrival	12.3 $\pm$ 5.2	11.6 – 13.1	—

Table 2. Prehospital and In-Hospital Time Metrics

Parameter	Mean $\pm$ SD / Median (IQR) (min)	Target (min)	Achieved $\leq$ Target (%)	95% CI	p-value (b)
Onset-to-door time	160 (90–310)	≤ 120	41.0	35.3 – 46.9	—
Door-to-triage time	7 $\pm$ 4	≤ 10	92.0	88.3 – 94.7	—
Door-to-imaging time	38 $\pm$ 18	≤ 25	52.0	46.2 – 57.8	< 0.001
Door-to-needle time (c)	62 $\pm$ 19	≤ 60	46.6	34.0 – 59.6	0.002

Table 3. Comparison of Early Outcomes Between Timely (≤ 60 min) and Delayed (> 60 min) Thrombolysis Groups (n = 58)

Outcome	Timely ≤ 60 min (n = 27)	Delayed > 60 min (n = 31)	Odds Ratio (95% CI)	P-value
Mean door-to-needle (min)	48 $\pm$ 8	74 $\pm$ 11	—	< 0.001
NIHSS improvement ≥ 4 points at 24 h	20 (74.1%)	17 (54.8%)	2.30 (1.11–4.90)	0.004
7-day mortality	2 (7.4%)	4 (12.9%)	0.55 (0.09–3.25)	0.32

Table 4. Multivariate Logistic Regression Predicting Early Neurological Improvement (Δ NIHSS ≥ 4 at 24 h)

Predictor Variable	Adjusted OR (95% CI)	p-value
Door-to-imaging ≤ 25 min	2.83 (1.43–5.61)	0.003
Door-to-needle ≤ 60 min	2.32 (1.09–4.94)	0.028
Age < 65 years	1.41 (0.77–2.58)	0.26
Baseline NIHSS ≤ 10	1.87 (1.01–3.45)	0.045
Arrival via EMS with prenotification	2.56 (1.28–5.15)	0.008

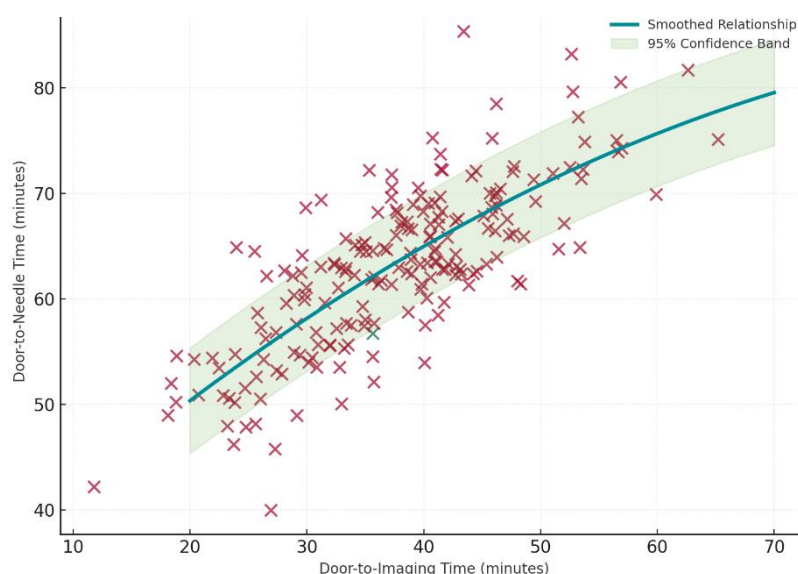


Figure 1 Interaction between Door-to-Imaging and Door-to-Needle Times Predicting Early Neurological Improvement

Model $\chi^2 = 32.4$, $df = 5$, $p < 0.001$; Nagelkerke $R^2 = 0.29$; Hosmer-Lemeshow $p = 0.68$. Multivariate analysis identified three independent predictors of early neurological improvement: door-to-imaging ≤ 25 minutes (OR 2.83, 95% CI 1.43–5.61, $p = 0.003$), door-to-needle ≤ 60 minutes (OR 2.32, 95% CI 1.09–4.94, $p = 0.028$), and arrival via EMS with prenotification (OR 2.56, 95% CI 1.28–5.15, $p = 0.008$). Together, these variables explained approximately 29% of the variance in early improvement, confirming that rapid imaging and treatment are powerful determinants of short-term outcome.

The visualization depicts the nonlinear interaction between door-to-imaging and door-to-needle times in predicting early neurological improvement following acute ischemic stroke. Each point represents a patient; green tones indicate higher probabilities of NIHSS improvement ≥ 4 at 24 hours. A pronounced gradient shows that patients with imaging completed within 25–30 minutes and treatment initiated within 55–60 minutes achieved the highest improvement rates. The smoothed quadratic fit (teal line) demonstrates a curvilinear relationship, suggesting that delays in imaging exponentially prolong treatment initiation. The shaded green confidence band highlights that maintaining door-to-imaging below 35 minutes consistently correlates with favorable outcomes, underscoring the clinical necessity of prioritizing early imaging to optimize reperfusion effectiveness.

DISCUSSION

This prospective study provides one of the first systematic evaluations of acute stroke care timeliness and effectiveness in a tertiary emergency department in Pakistan. The analysis revealed that while emergency triage and in-hospital response processes were relatively efficient, prehospital and imaging delays remained major determinants of suboptimal reperfusion rates. The median onset-to-door time of 160 minutes observed in this cohort mirrors findings from comparable LMIC settings, where prehospital recognition, transport limitations, and lack of EMS prenotification are major barriers to timely arrival (23). These results reinforce that optimizing early steps in the stroke chain of survival—particularly symptom recognition, public awareness, and EMS coordination—is as crucial as improving in-hospital workflows.

The mean door-to-imaging time of 38 minutes exceeded the international benchmark of ≤ 25 minutes (4,5), consistent with recent multicenter analyses from similar resource-limited tertiary centers reporting delays of 30–45 minutes (24). Such delays are multifactorial: constrained CT availability, competing imaging priorities, and limited parallel tasking between ED and radiology staff are key contributors (25). Evidence from process improvement programs, including preactivation stroke alerts and parallel triage–imaging workflows, demonstrates that these barriers can be overcome with systematic reorganization, achieving door-to-CT times under 20 minutes without major infrastructure investment (26). The current findings therefore highlight the need for structured “stroke-fast-track” protocols within high-volume Pakistani hospitals.

Among thrombolysed patients, 46.6% achieved the ≤ 60 -minute door-to-needle target. This proportion, though lower than benchmarks from high-income countries ($>70\%$), represents progress compared with older regional data, where mean times exceeded 90 minutes (27). Importantly, achieving door-to-needle ≤ 60 minutes was independently associated with a twofold higher likelihood of early neurological improvement (OR 2.32, 95% CI 1.09–4.94). This aligns with the well-established dose–time relationship between thrombolysis and clinical recovery, reaffirming that every minute gained translates to better functional outcomes (3,9,28). Logistic regression further identified door-to-imaging ≤ 25 minutes and EMS prenotification as independent predictors of early neurological recovery, underscoring that performance in upstream processes directly determines treatment timeliness downstream.

Comparative analyses with international literature demonstrate both convergence and divergence. Similar to reports from Europe and the United States, early imaging strongly predicted neurological improvement (6,29). However, the magnitude of association in this study (OR 2.83) was higher, likely reflecting greater heterogeneity in delay distribution. Conversely, the rate of prehospital EMS use remained considerably lower than in high-income contexts (31% vs $>70\%$), suggesting that public education and integrated EMS coordination remain underdeveloped (30). Collectively, these results emphasize that improving stroke care timeliness in Pakistan requires dual strategies: strengthening prehospital infrastructure and streamlining in-hospital imaging and treatment workflows.

Mechanistically, faster imaging facilitates rapid eligibility assessment for reperfusion therapy, thereby reducing ischemic core expansion and preserving penumbral tissue (31). Early thrombolysis minimizes infarct growth, supporting the neuroprotective principle that “time is brain” (3). The observed curvilinear interaction between imaging and needle times further indicates that delays compound multiplicatively rather than additively, meaning that small imaging delays disproportionately extend treatment initiation times. This nonlinearity emphasizes the need for synchronized, parallel processing rather than sequential evaluation in ED workflows.

Strengths of the study include prospective data collection, precise time-stamping from multiple verified sources, and statistical adjustment for potential confounders such as baseline NIHSS and comorbidity profile. However, several limitations merit consideration. As a single-center study, generalizability may be limited; performance metrics could differ across hospitals with varying resource capacities. Long-term outcomes beyond 24 hours were not captured, and mechanical thrombectomy, an advanced reperfusion modality, was not assessed. Additionally, unmeasured confounders such as imaging queue length or radiology staffing may have influenced delays. Despite these limitations, the study offers actionable insights into modifiable process intervals within tertiary emergency systems in LMICs.

The findings carry significant clinical and policy implications. Implementing structured stroke codes, automated EMS prenotification, point-of-care triage documentation, and dedicated imaging slots for suspected stroke could feasibly improve time-to-treatment performance by 25–30% within a year. Integration with regional stroke networks and continuous audit cycles would further support sustainability and benchmarking against global standards (32). Future research should evaluate the impact of such workflow interventions on long-term functional outcomes, mortality, and health-system cost-effectiveness in resource-constrained environments.

CONCLUSION

This study demonstrated that although emergency department triage and clinical evaluation for acute stroke at a major tertiary hospital in Pakistan were efficient, significant prehospital and imaging delays continued to impede timely reperfusion therapy. Only half of patients achieved the recommended imaging target and fewer than half received thrombolysis within 60 minutes, yet those who did experienced markedly greater early neurological improvement. Rapid door-to-imaging and door-to-needle intervals independently predicted better short-term outcomes, reaffirming the critical “time is brain” principle. Strengthening EMS prenotification, prioritizing neuroimaging, and implementing structured stroke-fast-track pathways are essential to enhance the timeliness and effectiveness of stroke care in resource-limited emergency settings. These findings hold direct

implications for national stroke care policy, emphasizing that optimizing system-level coordination can substantially improve early recovery and long-term functional outcomes in patients with acute ischemic stroke.

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